Ecology and distribution of *Nardus stricta* L. (Poaceae) – an alien invader into New Zealand

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Abstract

The European matgrass *Nardus stricta* L. (Poaceae), a perennial tussock grass native to Central and Eastern Europe, was first recorded in New Zealand in 1904. A brief description of the species is given, and the ecology of *Nardus stricta* in its native habitat, and global invasion patterns are briefly summarised. Current knowledge of its distribution within New Zealand is presented based on records from New Zealand herbaria, databases, private sources, and own observations. Three patterns are identified which characterise the current distribution: the species is mainly found (1) on the South Island, (2) on damp soil (e.g. swampy pasture, ephemeral wetlands, kettle depressions, seepages etc.), and (3) in areas that are used for pastoral grazing. Due to the species' characteristics and the potential impact on indigenous biodiversity and pastoralism, it is recommended that *Nardus stricta* be regarded as a potential environmental weed in New Zealand. It is most likely to invade low stature vegetation on acid soils, e.g. cushion communities or ephemeral wetlands, and invasion is probably assisted by grazing.

Keywords: exotic species - Nardeae - distribution map - habitat preference.

Introduction

The European matgrass *Nardus stricta* L. (Poaceae) (monotypic genus, *Nardus* hereafter), a perennial tussock grass native to Europe, was introduced to New Zealand approximately 100 years ago (Meusel *et al.* 1965). Currently, little is known about *Nardus* in New Zealand. Due to its growth form and its ability to dominate extensive areas and to replace other plants, the species might be a potential serious environmental weed, both for pastoralism and nature conservation. Already listed as a "noxious weed" in

the USA (United States Department of Agriculture 2004), in New Zealand *Nardus* is not yet recognised as an environmental weed (M. Newfield & C.J. West, Department of Conservation, pers. comm.). The aim of this paper is thus to identify the weed potential of *Nardus* in New Zealand. A description of the species is given, the ecology of *Nardus* in Europe is summarised briefly along with global invasion patterns, and current knowledge about the species distribution in New Zealand is presented.

The ecology of *Nardus stricta* L. (Poaceae) based on knowledge from Europe

General features

Nardus is a wiry, 10 - 40 (-60) cm tall and densely tufted perennial tussock grass with tillers closely packed on laterally branching rhizomes (Figure 1). Leaves are greyish-green and blades are stiff, sharp-pointed and tightly inrolled (Hubbard 1992; Edgar & Connor 2000). Outer leaves of tussocks are spreading at right angles to the sheaths when mature (Figure 1). The inflorescence is a slender unilateral spike with up to 20 spikelets. The single flowered spikelets are born in depressions forming two rows along one side of the spike axis. Flowers are hermaphroditic and protogynous, and apomictic seed production has been suggested (Chadwick 1960a).

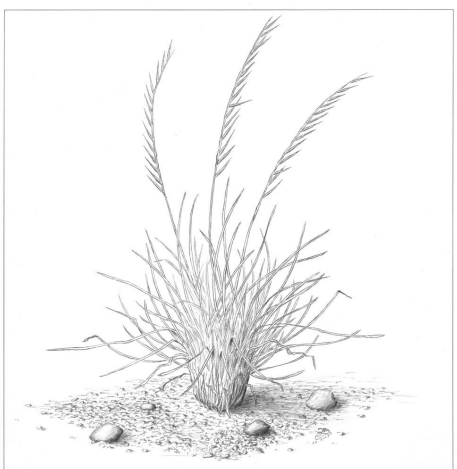

Figure 1. A single tussock of *Nardus stricta*. Note the outer leaves which are spreading at right angles to the sheaths, and the unilateral spikes with slender, single-flowered spikelets. Drawing kindly provided by J. Weinbecker.

Growth form and regeneration

The growth of the rhizomes around the perimeter and the closeness of the shoots result in a hemispherical clump giving the species its typical caespitose growth form (Zhukova 1974). In dense stands *Nardus* often forms a thick mat (hence the common name matgrass), and due to trampling it can adopt a flattened growth form (Grime *et al.* 1988). Limited growth and branching of the rhizome system followed by decay of the older rhizomes can result in daughter plants (Chadwick 1960a). *Nardus* can also regenerate from detached pieces of rhizome (Chadwick 1960a; Grime *et al.* 1988). However, *Nardus* does not produce stolons and lateral spread by vegetative reproduction is thus limited in distance. Reproduction by seed is important for colonisation of bare ground (King 1960), but is less important in closed vegetation (Grime *et al.* 1988). Seeds are rarely seen to germinate in the field, but are capable of germination (Chadwick 1960a). Clumps of *Nardus* approximately 20 cm in diameter can produce up to 2000 florets under favourable conditions. Dispersal of the detached florets is thought to occur "through the agency of grazing

animal, wind, rain and snow" (Chadwick 1960a).

Competitive ability

Nardus is a relatively slow growing species (Bradshaw *et al.* 1958, 1964; Grime *et al.* 1988) and does not compete successfully with other species in more fertile habitats (Chadwick 1960a). This is because *Nardus* is intolerant of shade and can be shaded out where it grows with potentially taller plants (Chadwick 1960a). However, on poorer substrates (Chadwick 1960a) and where grazing reduces the competitive ability of other species (Welch 1986; Grant *et al.* 1996), *Nardus* effectively competes with other plants. Once established it can exclude smaller species due to its growth form, which allows the plant to suppress surrounding vegetation (Zhukova 1974). Its potential to dominate extensive areas is well known from Europe (Tansley 1939; Grime *et al.* 1988; Ellenberg 1996).

Habitat and distribution of Nardus *in its native range*

Nardus occurs in a great variety of habitats, but mainly acidic and damp but not permanently wet soils, avoiding regions with less than 500 mm average annual precipitation (Tansley 1939; Chadwick 1960a). It is present on soil types ranging from brown earths, podsols, gleys, peat podsols to peats, but tends to be most abundant where the substrate is relatively calcium-deficient. The distribution of *Nardus* seems neither to be limited by topographical preferences nor by extremes of temperature (Chadwick 1960a).

Nardus has a wide natural geographical distribution and is present from the mountains of southern Europe and the plains of western Asia to western Greenland (Meusel *et al.* 1965). It occurs from sea level to quite high altitudes, commonly to 1000-2000 m altitude, and ascending to 3000 m in the Swiss Alps and to 3500 m in the Grand Atlas mountains (Chadwick 1960a).

Nardus is currently shrinking in distribution and declining in abundance in its native range in central Europe (Pott 1995; Ellenberg 1996). The main reasons are thought to be fertilisation and intensification of land use, afforestation, or abandonment of farm land (Mertz 2000). Apart from *Nardus* communities that naturally occur at higher altitudes of mountainous areas, most at lower altitudes are of anthropo-zoogenic origin, i.e. they arose from deforestation and subsequent grazing of the areas by sheep, cattle, and goats (Wilmanns 1998). Due to land use changes in central Europe, *Nardus* communities are now regarded as threatened there (Pott 1995). However, in the British Isles, *Nardus* has increased in distribution and abundance and is considered to be a major problem for pastoralism due to its low productivity and palatability (Fenton 1936, 1937; Rawes 1961; Grant *et al.* 1996; Armstrong *et al.* 1997).

Global invasion patterns

Nardus has been introduced to several other countries. The species is listed as a 'noxious weed' in the USA where it is found in the north eastern states of Michigan, New York, New Hampshire and Massachusetts, and in the north western states of Idaho and Oregon (United States Department of

Agriculture 2004). Furthermore, there are records in north Canada from Quebec, Nova Scotia and Newfoundland, and from Greenland, though it is not clear whether it is introduced or indigenous in the latter two regions (Chadwick 1960a). In Central America, *Nardus* has been found in upper pastures at the Volcán Turrialba, Costa Rica, at 3000-3300 m altitude (Pohl 1987). Early introductions of mixtures of European pasture grasses, which were imported to provide forage for dairy cattle, are thought to be the seed source for its establishment (Pohl 1987). In South America, *Nardus* has been reported from the Falkland Islands, although the record is doubtful since subsequent botanists were unable to confirm it and no herbarium specimen exists (Nicora 1978). In the South Pacific, *Nardus* occurs in swampy areas at Mount Huxley near Queenstown in western Tasmania, a region with an annual mean precipitation of about 2500 mm (J. Kirkpatrick, University of Tasmania, pers. comm.).

Nardus invasion in New Zealand

Invasion history and current state of knowledge

The earliest record of *Nardus* in New Zealand is from Meusel *et al.* (1965) who report, without substantiation, that the species had been found in New Zealand since 1904. In contrast, Edgar *et al.* (1991) note the first *Nardus* record in New Zealand from 1935 as reported by Allan (1935) from the Dunedin area. Edgar & Connor (2000) report that the species occurs on the Volcanic Plateau (Waimarino) in the North Island, and that it is scattered and local in the South Island, not being reported from Westland and Fiordland. However, there is no information given on distribution records of *Nardus* in New Zealand.

Distribution records

New Zealand museums and other institutions were contacted and asked for herbaria and database records to gather information on distribution records of *Nardus* in New Zealand. There are twenty-one records for *Nardus* in New Zealand (Table 1), and twenty of them are distribution records whereas one is cultivated material only (Figure 2, Table 1). There was only one location in the North Island, and one from the Chatham Islands. Here it most likely arrived in seed mixtures for pasture establishment (B.P.J. Molloy, Landcare Research, pers. comm.). In the South Island, almost all records were from the eastern side of the Main Divide. The dates of the records ranged from 1926 to 2003 and most records were old (65% are older than 30 years). From the distribution records three patterns emerge:

(1) *Nardus* is mainly found on the South Island. The distribution records suggest that *Nardus* occurs throughout the South Island except the west coast (Table 1, Figure 2). In the North Island, the species is confined to the higher mountain region of the Volcanic Plateau. An explanation for this distribution pattern might be that the macroclimate of the South Island is most suitable for the species. In its native habitat *Nardus* occurs throughout Europe but is confined to the higher mountain regions in southern Europe (Chadwick 1960a). The South Island has a climate more

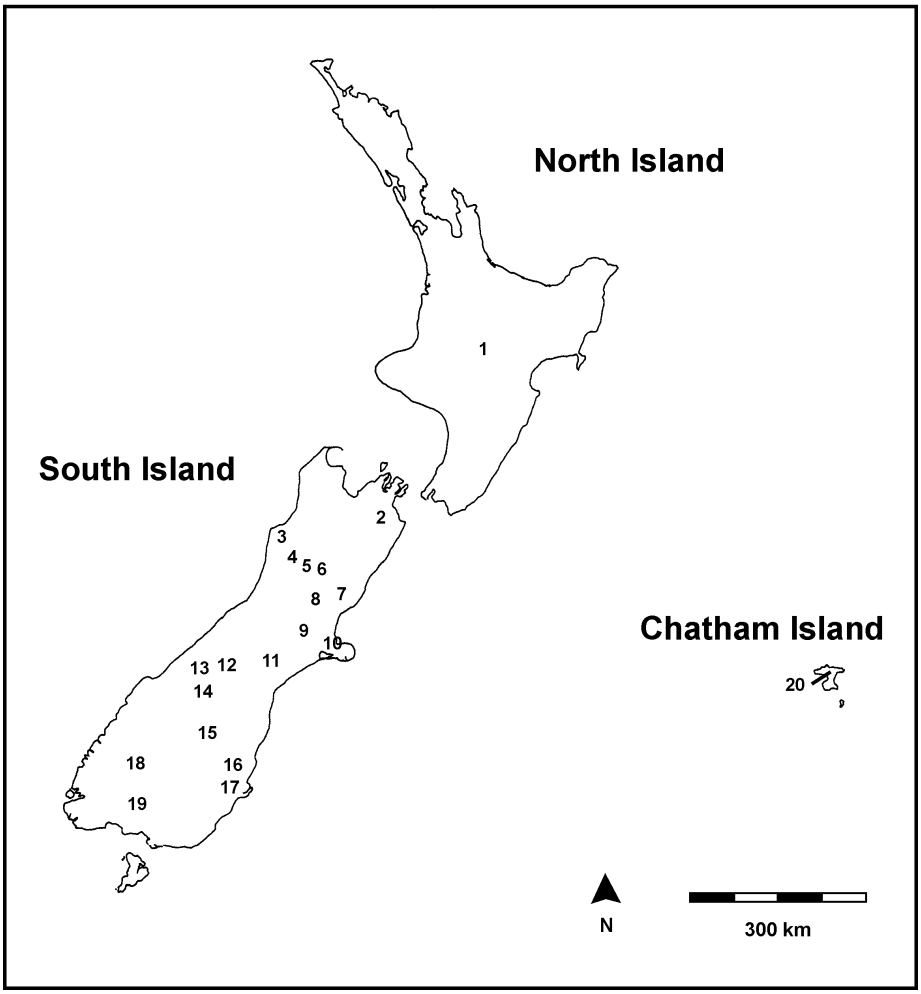

Figure 2. Distribution records of *Nardus stricta* in New Zealand. Numbers (1-20) refer to locations listed in Table 1.

similar to central and eastern Europe, where *Nardus* has its native core distribution. The climate of the South Island is more temperate and cooler than the climate of the North Island, and the South Island is much more mountainous (Cochrane 1973). Previously, the climates in the home ranges of potential invaders have been used to predict the long-term potential of alien invasive species ('climate matching'; Mack 1996; Hoffmann 2001; Welk *et al.* 2002). However, the predictive power of this approach has varied and it does not appear to be a very reliable circumscription of invasive limits (Wilson *et al.* 1992; Mack 1996).

(2) Damp soils are the preferred habitat. Many distribution records suggest that the species occurs most frequently on damp ground in New Zealand (Table 1). The preferred habitat seems to be damp soil within pasture and grasslands, but also red tussock (*Chionochloa rubra*) wetland, *Sphagnum* communities, subalpine bogs and

Table 1. Records (distribution and cultivated material) in New Zealand of invasive European matgrass *Nardus stricta* L. (Abbreviations: AK = Auckland War Memorial Museum Herbarium; BW = BioWeb database of the Department of Conservation; CHR = Landcare Research Herbarium, Lincoln; MPN = Massey University Herbarium; WELT = Te Papa Museum of New Zealand)

Code	Location	Habitat	Observer	Date	Source/ID	Remarks
Distribution records						
1	Raetihi, Volcanic Plateau (Waimarino)	Swampy pasture, damp ground	A.G. Brown, P. Hatton & C.C. Ogle	1971 and 1992	Edgar & Connor (2000), BW, MPN 28245, CHR 477738	Light infestation in area 100m x 25m, present at least two years, fruiting
2	Renwicktown, Marlborough	Old native pasture	J.R. Beggs & A.J. Healy	1955	CHR 82734	
3	Denniston	Old pack track, in clearing	V.D. Zotov, D. & G.C. Kelly	1955 and 1973	CHR 92602 A and B, CHR 250173	Scenic Reserve
4	Reefton, North Westland	On coarse gravel bench	R.O. Gardner	1997	AK 249614, BW	Rainy Creek, old battery site, dominant
5	Between Reefton & Rahu Saddle	Swampy sown pasture	F.E. Hoskins	1968	CHR 196618	
6	Maruia	Sheep pasture	P.A. Dune	1962	CHR 132306	Rare
7	Culverden, Canterbury	?	P. Thaine	1955	CHR 96166	Dense stand of approximately 100 acres
8	North Canterbury	?	W.L. Kay	1964	CHR 156705	
9	Lees Valley, Canterbury	Red tussock wetland and pasture	A. Baird & C.D. Meurk	1991	CHR 472549	In open paddock
10	Lyttleton Hills	?	J.B. Armstrong	Prior 1926	WELT	

11	Ashburton River, near Alford Scenic Reserve	Slope with *Sphagnum*	B.H. Macmillan	1972	CHR 225694	One patch only seen
12	Irishman Creek Station, Lake Pukaki	Damp soil, west aspect	B.H. Macmillan & A.R. Mitchell	1970	CHR 206760	
13	Ferintosh Station, Lake Pukaki	Wet depressions in tussock grassland, subalpine bog	H.M. Sieowright, W.D. Kissling	1959 and 2003	CHR 112363, BW Own observations	Noticed in 1956 increasing. 2003: dominant on damp soil
14	West side of Lake Pukaki	Wet depressions and damp places within tussock grassland	T.G.C. Kerr, W.D. Kissling	1966 and 2003	CHR 156767, BW Own observations	2003: dominant in wet depressions within grassland
15	Becks, near St. Bathans, Central Otago	Pasture	R.K. Dawin & A.J. Healy	1966	CHR 172530	Isolated clump
16	Macraes Flat, Nenthorn Reserve	Damp soil within tussock grassland	J. Pearce & K.A. Ford, W.D. Kissling	1999 and 2003	CHR 542904 Own observations	
17	Town Belt, Dunedin	?	J.M. McCaskill	1931	CHR 4117	
18	Burwood Station, Southland	?	P.P. Gow	1962	CHR 132295	Forming mat and taking charge of the area
19	Nightcaps, Southland	?	B. Drummond	1947	CHR 51508 and CHR 61911	Plant was grown at Botany Division, DSIR Glasshouse
20	Chatham Island	Paddock grazed by sheep, damp soil, deep peat	B.P.J. Molloy	2002	B.P.J. Molloy pers. comm.	
Cultivated material						
21	Lees Valley, Canterbury	Cultivated at Lincoln	L.W. McCaskill	1963	CHR 224701	Lincoln experimental garden voucher

ephemeral wetlands. In its native habitat, Tansley (1939) reported from the British Isles that 'it [*Nardus*] occurs in a great variety of habitats, whose common character seems to be a soil of acid and damp but not permanently wet raw humus or peat, with stagnant or nearly stagnant soil water'. Grime *et al.* (1988) view *Nardus* as being 'essentially a dryland species which occasionally extends into soligenous mire', being, however, 'particularly abundant in areas of high rainfall'. Thus, soil moisture seems to be very important, no matter whether provided by rain or by the hydrology of the habitat.

(3) Pastoralism and grazing seem to be correlated with the occurrence of *Nardus*. Many distribution records suggest that pastoralism and grazing is associated with the occurrence of *Nardus* (Table 1), and grazing has been found to favour *Nardus* in its native habitat in Europe (Fenton 1936, 1937; Grant *et al.* 1996). The species is of low palatability (Thomas & Fairbairn 1956), and is avoided by grazing sheep (Fenton 1936, 1937; Grant *et al.* 1996). When grazed, *Nardus* increases in abundance at the expense of other species (Ellenberg 1996; Grant *et al.* 1996). Given the extent of sheep farming in New Zealand, *Nardus* may have the ideal conditions to further spread and increase in abundance and dominance.

Situation at Lake Pukaki, South Canterbury

The current occurrence of *Nardus* was checked at the western side of Lake Pukaki, South Canterbury (Kissling 2004). At this location, *Nardus* was first noticed in 1956, and subsequently recorded in 1959, 1966 and 1970 (Table 1, code 12-14). Now (in 2003), *Nardus* often forms dense and extensive, almost monospecific stands. The main habitats are wet depressions and damp soil within semi-natural tussock grasslands on lateral moraine including wet or seasonally ponded kettle depressions (Figure 3), edges of tarns, ephemeral wetlands, seepages (Figure 3), subalpine bogs, and ditches along road sides. Most sites are on pastoral land; however, *Nardus* has recently invaded ephemeral wetlands on conservation land (Pukaki Scientific Reserve, managed by the Department of Conservation) and recruitment studies suggest that the species is spreading (Kissling 2004).

Figure 3. Dense populations of *Nardus stricta* (light coloured in the centre) within tussock grassland (surrounding) on lateral moraine at approximately 900 m above sea level at the western side of Lake Pukaki, Canterbury, New Zealand. Top: A seasonally ponded kettle depression invaded by *Nardus stricta*. Bottom: A seepage completely covered by *Nardus stricta*. (Photos: W.D. Kissling)

Spread and invasion potential

The current spread rate of *Nardus* is not known. The situation along the western site of Lake Pukaki suggests that *Nardus* is expanding its range at least locally (Kissling 2004). Many biological invasions are characterised by a lag phase, i.e. a time lag between the first establishment, and the beginning of spontaneous spread (Kowarik 1995). It would be desirable to know whether *Nardus* has gone beyond its lag phase and has started to spread more widely. However, this could only be achieved by monitoring currently invaded sites.

Due to the wide range of environmental conditions *Nardus* can tolerate (Chadwick 1960a; Kruijne 1965), it is difficult to make any predictions of its invasion potential. *Nardus* is most likely to occur on acidic, poor soils, and might be limited to wet depressions in regions with low mean annual precipitation (Chadwick 1960a). It will probably be most invasive in open, low stature vegetation, or where grazing reduces the competitive ability of other plants. The species could successfully invade grasslands as reported from Europe (Fenton 1936, 1937; Chadwick 1960b; Rawes 1961; Grant *et al.* 1996). Furthermore, *Nardus* is potentially a successful invader into alpine and subalpine cushion plant communities (Gibson & Kirkpatrick 1985), into ephemeral wetlands with their turf and sward vegetation (Johnson & Rogers 2002), and into kettle hole wetlands (Johnson 1994; Johnson & Jackson 1999). In contrast, *Nardus* is less likely to be a problem in densely vegetated wetlands, e.g. those dominated by *Chionochloa rubra* (Wardle 1991), due to being shaded out by taller plants.

Control

Currently, *Nardus* control methods are largely absent. No biological control agents exist, and herbicide treatments have been used to kill only individual tussocks (Callihan & Miller 2003). Whatever control method is chosen, attention should be given to possible side-effects on non-target organisms.

Conclusions

Environmental weeds are alien plant species that threaten local native species or ecosystem processes (Reid 1998). Due to its growth habit *Nardus* has the ability to dominate extensive areas and to replace other plants, while the habitats invaded by *Nardus* in New Zealand constitute ecosystems with high conservation value (Mark 1992; Johnson & Jackson 1999; Johnson & Rogers 2002). Ecosystem processes, for instance the hydrological system of seasonally ponded kettle depressions or ephemeral wetlands, could be altered by *Nardus* invasion. Furthermore, the species is a problem for pastoralism due to its unpalatability to stock and its low productivity. Based on these arguments it is recommended that *Nardus* be regarded by relevant management agencies (e.g. Department of Conservation and Regional Councils) as a potential environmental weed in New Zealand. However, more information is needed on its distribution, establishment, spread and impact in New Zealand. We would thus like to encourage all New Zealand botanists, ecologists, conservationists, farmers, weed managers, agriculturists, and all other interested people, to watch out for *Nardus* in New Zealand and to record distribution records of the

species, lodging voucher specimens at appropriate herbaria.

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